

AN OVERVIEW OF FUNGAL ANTAGONISTS POTENTIAL AS BIOCONTROL AGENTS AGAINST PADDY CROP PLANT DISEASES OCCURING IN THE CAUVERY-DELTA ZONE

BASOBI MUKHERJEE & N.UMA MAHESWARI

PG and Research Department of Microbiology, S.T.E.T Women's College, Mannargudi, Tamil Nadu, India

ABSTRACT

The objective of this study is to review the research work on biological control of various paddy crop plant diseases occurring in the Cauvery-Delta Zone. Due to the presence of plant pathogens, serious losses to agricultural products occur every year. Therefore, plant diseases including pathogens can be treated using biological control methods instead of chemical control methods. According to the plant pathology, the term "bio control" refers to the use of microbial antagonists to suppress diseases. There are several modes of actions of bio control-active microorganisms in controlling plant diseases like hyper parasitism, predation, antibiosis, cross protection, competition for site and nutrient, and induced resistance. Bio control agents application can be made using various methods that include: application directly to the infection site, application at one place and occasional application. Mainly, application of bio control products can be found against seed borne and soil borne pathogens. These products have been found to be effective in protecting several major crops such as wheat, rice, corn, and cotton against pathogens. A definite improvement has been found in the biological control of plant diseases, but still requires much more development and investigations to solve the upcoming and previous issues. As a requirement of having more effective biological control strategies in the future, it is difficult to carry out more research studies on some less developed aspects of bio control, understanding the importance of the impact of environmental factors on bio control agents, mass production of bio control agents. The bio control of plant diseases have a bright and promising future outlook and with the growing demand for bio control products, it is highly remarkable to use the biological control as an effective way to control plant diseases, increase crop yield, protect the environment and biological resources and approach a sustainable agricultural system.

KEYWORDS: *Plant Diseases, Cauvery-Delta Zone, Paddy Crop, Antagonistic Fungi, Mechanisms, Application, Future Outlook & Development*

Received: Jun 03, 2017; **Accepted:** Jun 20, 2017; **Published:** Jul 17, 2017; **Paper Id.:** IJBRAUG20173

INTRODUCTION

There are certain global impacts on the use of Sustainable Agriculture. System of Rice Intensification (SRI): A Sustainable Agriculture method produces higher yields, when compared to conventional methods for the same crop. Sustainable Agriculture is able to produce enough food on a global per capita basis to maintain the current human population, and potentially an even larger population, without putting more farmland into production. Leguminous crops are able to fix enough nitrogen to replace the amount of synthetic fertilizer (Badgley et al., 2007). (Pretty et al., 2003) submitted a review of 286 sustainable agricultural projects carried out between 1999 and 2000 across eight categories of farming systems in 57 developing countries in Africa, Asia, and

Latin America.

- Increase in yields was seen by approximately 79%, due to the adoption of SA practices.
- On an average, the production of food per family increased by 1.7 tons yearly (rise by 73%).
- Below mentioned are the impacts of organic projects or surveys conducted based on agriculture in Africa:
- Crop yield was risen by an average of 116% in total, and
- There was 28% increase found for the projects in East Africa.

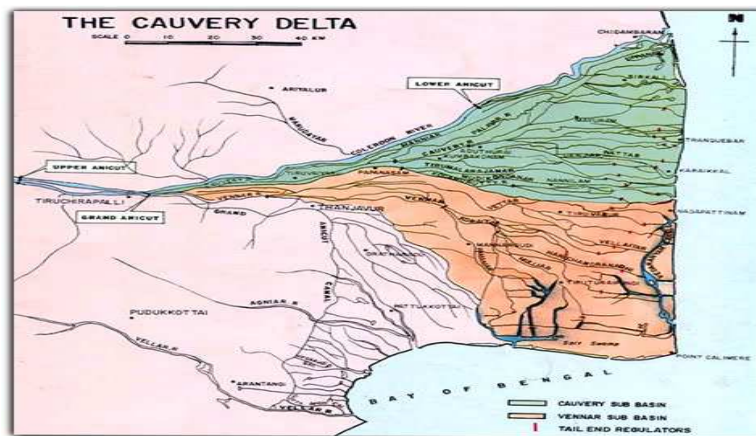


Figure 1: Area Map of the Cauvery Delta Zone

The research on biological control of paddy pathogens was started recently, mainly in the 1980s. Presently, research is still concentrated on the identification, evaluation and formulation of potential biocontrol agents for deployment. Several numbers of fungus, bacteria, virus, nematode and mycoplasma-like organisms cause disease to paddy plants. Among these, the fungal diseases like Blast (*Pyricularia grisea*), Leaf smut (*Entyloma oryzae*), Brown spot (*Bipolaris oryzae*), Stem rot (*Sclerotium oryzae*), Sheath blight (*Rhizoctonia solani*), Sheath rot (*Sarocladium oryzae*); bacterial disease such as Bacterial blight (*Xanthomonas oryzae*) and viral disease such as tungro (rice tungro virus) are considered to be most important. These diseases are taken as a serious constraint for rice production.

Generally, the use of host plant resistance and chemical pesticides mainly aim at prevention of outbreak or epidemics by rice disease management as strategies. Undesirable changes in the environment can be caused due to the continuous or daily use of chemicals that have toxic effects. Chemicals are mainly of high cost that makes it difficult to be purchased by the poor farmers in India, where, more than 70% of the world's rice is cultivated. Resistance breakdown in paddy plants may tend to occur due to the large-scale and long-term use of resistant chemicals, which as a result, changes the characteristics of pathogens. However, research during the previous two decades has found another potential option for rice disease management which is biological control of rice diseases. Biocontrol involves special significance due to an eco-friendly and cost effective strategy, which can be used in combination with other strategies for a greater level of protection with sustained rice yields.

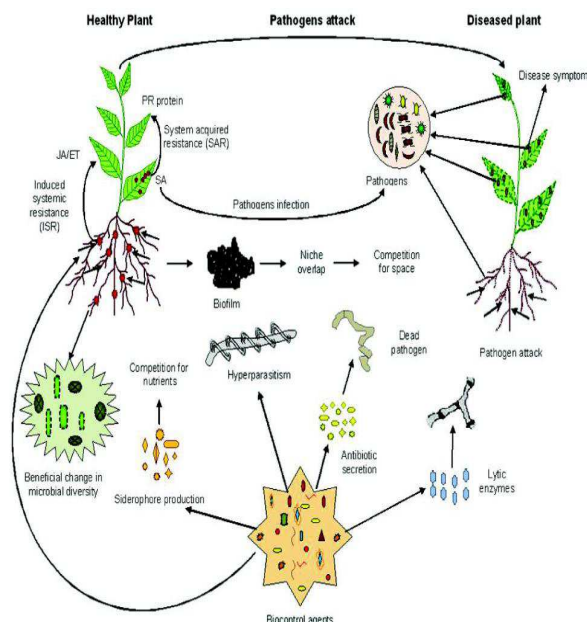


Figure 2: Mechanism Showing Biological Control Against Plant Diseases

RICE (PADDY) (*International Rice Research Institute, January 6, 2009*)

Rice (*Oryzasativa L.*) is among the most important cereals in the world. It is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production. Rice can be found in many shapes, colours and sizes. Rice cultivation is well-adapted to countries and regions with low labour costs, and high rainfall, as it is labour-intensive to cultivate and requires a lot of water. Rice acts as the energy source in diets for many countries located in Asia, North and South America and Africa. Rice gives 20% of the world's dietary energy supply. The production of rice worldwide has increased gradually during the years, from about 200 million tonnes of rice to over 678 million tonnes. The three largest producers of rice, presently, are China, India and Indonesia.

There are certain climatic factors on which yield of rice depends:

- Temperature - Rice requires high temperature above 20°C (68°F) but not more than 35 to 40°C (95 to 104°F) for growth. Optimum temperature is around 30°C and 20°C.
- Solar radiation –The amount of solar radiation received within 45 days determines final crop output.
- Atmospheric water vapour – High water vapour content (in humid tropics) leads to unusual stress which favours the spread of fungal and bacterial diseases.
- Wind – Light wind transports CO₂ to the leaf canopy but strong wind causes severe damage and may cause sterility.

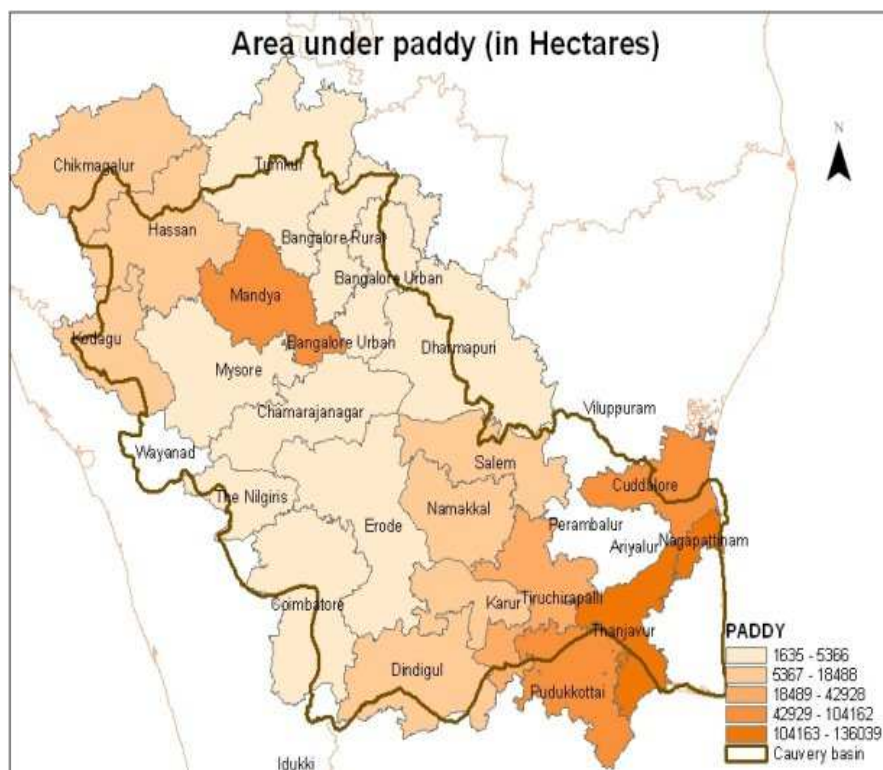


Figure 3: Area under Paddy Crop

MAJOR DISEASES CAUSED TO PADDY CROPS IN THE CAUVERY-DELTA ZONE

Bacterial Leaf Blight

The Bacterial leaf blight disease of rice is caused due to a gram-negative bacterium, *Xanthomonas oryzae* (*Xoo*), and is considered the most devastating bacterial disease throughout the world. This disease has also affected paddy plants in Australia, USA and several other countries (Ronald *et al.*, 1997). The symptoms of infection caused by *Xanthomonas* are decrease in dry weight, grain weight, and rise in presence of sterile grains number in the plant. Poor maturation of grain and easily broken grain during milling can also be observed as a result of infection. Depending on how much severe is the disease, the extent of damage can be gauged. The growth stage of the paddy crop should be highly monitored in order to understand at which stage the infection takes place. The temperate regions face more severe damage of paddy crops when compared to the tropics.

Bacterial Sheath Brown Rot of Rice (Miyajima, *et al.*, 1983)

This disease is recognized by longitudinal brown to reddish brown necrosis 2-5 mm wide extending along the entire length of the leaf sheath and blade. Affected leaf sheaths may show extensive water-soaking and necrosis. Glumes turn colourless before emerging from such panicles. Grains on affected tillers will become completely discoloured and sterile to nearly symptomless with only small brown spots. This disease was first reported to be caused by *Pseudomonas marginalis*, but the pathogen was subsequently renamed as the new species *Pseudomonas fuscovaginae*. This bacterial disease has been first reported from northern Japan and Central Africa and causes considerable losses.

Rice Blast

Rice Blast, caused by the fungus *Pyriculariaoryzae* Cav. is the most important disease of rice throughout the world, both in its distribution (Anonymous *et al.*, 1968; Pans *et al.*, 1976) and the damage it causes (Ouet *et al.*, 1972, 1980). Its high destructive potential causes serious yield losses; controlling this disease is therefore one of the main goals of rice growers. The presence of the disease was first reported in Spain. These infections affect all the plant organs and causes serious yield losses when the climatic conditions become favourable to the disease; over 90% of the plants get affected. *Pyriculariaoryzae* can also cause damage to any aerial part of a rice plant, although the leaves and panicles (are the most commonly affected organs. Leaf infection reduces the photosynthetic ability of the plant that leads to its death. Panicle infection is the one which causes the most important economic losses via yield reduction (Roumenet *et al.*, 1992)

Narrow Brown Leaf Spot of Rice

The disease narrow brown leaf spot of rice is caused due to the fungus *Cercosporajanseana*, which causes severe damage when the rice plants turn mature. The symptoms of infection include spotting of leaves that is found in greater number on susceptible varieties, also the disease causes leaf necrosis. Ripening of the plant prematurely, decrease in the amount of yield and reduction during milling occurs when this disease affects the paddy plant. More symptoms observed are short, linear and brown coloured lesions present commonly on the leaf blades. Lesions present on the leaves have a diameter of 2 millimetres to 10 millimetres in length and 1 millimetre in width. Lesions found on the leaf are thin, short and dark brown in colour on resistant varieties and, thick and light brown in colour on susceptible varieties (Ahmad *et al.*, 1991).

Leaf Smut of Rice

Leaf smut, caused by the fungus *Entylomaoryzae*, is a grain disease of rice first developed in Louisiana. It occasionally infects to epidemic levels in certain areas and is more common on rice grown in the northern parts of the country. The fungus germinates and produces spores that infect the grain. The disease first appears as a large grey to brownish green fruiting structure covered by a thin membrane that replaces one or more grains. The membrane ruptures, exposing orange spores. In the centre of the ball, is a hard structure called a sclerotium that replaces the grain. As the spore balls mature, they turn khaki green to black. Spores contaminate surrounding grains. Decrease in yields does not occur due to this disease, but the spores reduce the quality of the grain. The disease is more likely to occur at areas with high nitrogen rates and is more common on lately planted rice. Most varieties appear to have high levels of resistance, and therefore, disease control measures generally are not required (T. Ashizawa *et al.*, 2010).

Bacterial Leaf Streak of Rice

*Xanthomonasoryzae*pv. *oryzicola*(Fang *et al.*, 1957) Primary hosts - Rice, cereals, southern cut grass, annual wild rice. Symptoms include narrow, dark-greenish, water-soaked, interveinal streaks of various lengths, on the leaf blades. The lesions enlarge and turn yellow-orange to brown in colour. Sometimes, Amber coloured bacterial exudates can be seen on the lesions. It is difficult to distinguish between leaf blight caused by *X. oryzae*pv. *oryzae*, the main difference in the later stages of infection being the shape of the edges of the lesions; straight in leaf streak and wavy in leaf blight. Bacteria frequently enter through the damaged feeding sites associated with lepidopteron leaf rollers, leaf-folders and hispa beetles. This disease was first reported in Asia and Africa.

BIO CONTROL AGENTS – ANTAGONISTIC FUNGI

Due to plant diseases, every year nearly 10-20% of the total world food production decreases and this lead to loss of billions of dollars. Agriculture has been facing the destructive activities of numerous pests and pathogens from early times which lead not only to reduction of the yield of the crop, but also lose in terms of money and reduce the aesthetic value. However, the extended use of the synthetic chemicals during the last three decades has raised a number of ecological problems. In the recent years, scientists have diverted their attention towards inventing the potential of beneficial microbes. The plant pathogenic diseases cause a significant reduction of seed germination, seed quality thereby limiting potential yield of the rice plant.

Biological control refers to the use of one living microorganism to inhibit the growth and proliferation of another, undesirable one. The mechanisms through which bio control agents act are antibiosis, secretion of metabolites that are toxic, fungi lysis enzymes, parasitism and competition for nutrients. Nowadays, several biological approaches are gaining popularity and in use, including microbial antagonists like fungi and bacteria (Eckert and Ogawa *et al.*, 1988). *Trichoderma sp.* and *Gliocladium sp.* are becoming the promising biological control agents that help in the treatment of several plant pathogens. A large number of foliar and soil borne diseases can be controlled using *Trichoderma sp.* (Papavizas *et al.*, 1985).

Antagonist

An antagonist is a microorganism, which induces different mechanisms like production of lytic enzymes, antibiotics and competition for producing a damaging effect on other pathogenic organisms. There are two types of antagonism:

- Specific antagonism, which occurs when a particular species of microbe acts on the pathogen inoculums thereby, reducing the disease.
- General antagonism, which occurs when there is general activity of microbes that leads to the suppression of disease as well as the pathogenic microbes (Desai *et al.*, 2003).

Types of Biological Control (Hussey & Scopes *et al.*, 1985)

Biological control is of three types:-

- Introduction or classical biological control
- Augmentation biological control
- Conservation biological control

MECHANISMS OF BIOLOGICAL CONTROL (Aino *et al.*, 1997)

Antagonist microorganisms, such as *Trichoderma*, reduce growth, survival or infections caused by pathogens by different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme secretion.

Competition

This mechanism occurs when bio control agent or antagonist compete with the plant pathogen for the space and

nutrients availability. The antagonists reduce disease development by inhibiting the growth of pathogen in the rhizo sphere. For example, *Trichoderma harzianum* reduces collar rot in elephant foot yam by 80-85%.

Antibiosis

Trichoderma strains are known to produce antibiotics and toxins, which are volatile or non-volatile in nature, and have a direct effect on other organisms. Examples of such chemicals are trichothecin, sesquiterpine, and trichodermin that have antimicrobial effect on bacteria and fungi.

Mycoparasitism

In this mechanism, parasitism occurs during the interaction between two fungi. As a result, one fungus stops and kills the growth of other fungi. The mechanism covers different stages of interactions:

APPLICATION OF ANTAGONISTS

Biological control can be applied successfully in field, infected plant, and seed treatment provided there is enough knowledge and ability to manage (Baker *et al.*, 1987). Direct application of antagonists in the site of infection in increased quantity helps in killing the pathogen, seed coating and treatment with antagonistic fungi (Heydari *et al.*, 2004). Antagonists are also applied to fruit for protection in storage. Bio control microorganisms are applied at one place in low amount in single application type. These microorganisms then multiply and spread to other parts of the plant and provide protection against pathogens causing diseases in plants. Occasional application type maintains pathogen populations below threshold levels.

POTENTIAL ADVANTAGES OF BIOLOGICAL CONTROL (Parrella *et al.*, 1990)

- Decrease disease intensity leading to higher production
- Reduce the use of chemical fungicides and nematicides
- Reduce likelihood of undesirable effects (environment pollution, effects on non-target organisms, resistance development against pesticides) from chemical pesticide
- Provide greater flexibility in rice disease management
- Can play a key role in integrated management of rice diseases
- Safe for the users and the farming community

ADVANTAGES OF FUNGI AS BIO-CONTROL AGENTS

Bio control fungal agents reduce the application of chemical pesticides that are poisonous and harmful to the environment. Fungi are noble biological control agents for several reasons like, (a) fungal agents can generate by themselves on the plant surface and provide protection during plant growth, (b) these fungal agents does not affect living beings and thus can be used due to being safe, environment-friendly without any side-effects. (c) The fungal biocontrol agents can easily produce fungal spores in greater quantity that act as parasites for insects. Fungi have a wide range of hosts due to which multiple pests can be controlled using a single product.

RESEARCH AND DEVELOPMENT

Nowadays, growers are interested in reducing dependence on chemicals, so biological controls can be expected to play an important role in Integrated Pest Management systems (Jacobsen *et al.*, 2004). Good agricultural practices include appropriate site selection, crop rotations, tillage, fertility and water management; provide the foundation for successful pest management by providing a fertile growing environment for the crop. In terms of reliability, the greatest successes in biological control have been achieved in situations, where, environmental conditions are most controlled or predictable (Fravelet *et al.*, 2005). As research focuses on the various conditions needed for successful biocontrol of different plant diseases, the adoption of biological control agents in IPM systems is bound to be used in greater frequency in the coming years.

CONCLUSIONS AND FUTURE PROSPECTS

The Bio-control fungi usage will grow in the future, if scientists develop antagonistic fungal spores and mycelia successfully. It is necessary to well understand the biotic and abiotic interactions taking place in the environment with fungi, to know the optimal dosage and time of application. The susceptible host stage should be considered mainly, along with agricultural practices and environmental conditions. In sustainable agriculture, fungal biocontrol agents will play an important role in controlling the pests and thereby, improving the quality of all agricultural crops.

REFERENCES

1. Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Aviles-Vazquez, K., Samulon, A., and Perfecto, I. (2007). *Organic agriculture and the global food supply. Renewable Agriculture and Food Systems* 22(2):86–108.
2. Pretty J, Griffin M, Sellens M, Pretty C.J. (2003). *Green Exercise: Complementary Roles of Nature, Exercise and Diet in Physical and Emotional Well-Being and Implications for Public Health Policy.*
3. "The Rice Plant and How it Grows". International Rice Research Institute. Archived from the original on January 6, 2009.
4. Ronald, P.C. (1997). *The molecular basis of disease resistance in rice*, Plant Mol. Biol., 35:179-186.
5. Miyajima, K., Tani, A. A., and Akita, T. (1983). *Pseudomonas fuscovaginae* sp. nvm. Rev. Int. J. Syst. Bacteriol. 33:656-657.
6. Anonymous, (1968). *Distribution map of plan diseases. Commonwealth MycolInst Kew. N° 51, ed. 5.*
7. Pans, (1976). *Pest control in rice. Manual n° 3. Centre for overseas Pest Research. London. 295 pp.*
8. Ou S.H., (1972). *Rice diseases. Commonwealth MycolInst, Kew. 368 pp.*
9. Ou S.H., (1980). *A look at worldwide rice blast disease control. Plant Dis* 64, 439-445.
10. Roumen E.C., (1992). *Partial resistance to neck blast influenced by stage of panicle development and rice genotype. Euphytica* 64, 173-182.
11. Ahmad, M. and Mir, N.M. (1991). *Chemical control of brown spot of rice. Pl. Dis. Res.*6: 58-63
12. T. Ashizawa, M. Takahashi, J. Moriwaki and H. Kazu-yuki, (2010). "Quantification of the Rice False Smut Pathogen *Ustilagoideavirens* from Soil in Japan Using Real-Time PCR," *European Journal of Plant Pathology*, Vol.128, No. 2, pp. 221-232.
13. Fang, C.T., H.C. Ren, T.Y. Chen, Y. K. Chu, H. C. Faan, and S.C. Wu. (1957). *A comparison of the rice bacterial leaf blight organism with the bacterial leaf streak organism of rice and Leersiahexandra Swartz. ActaPhytopathol. Sinica* 3:99 -124

14. Eckert, J.W. and Ogawa, J.M.(1988).The chemical control of postharvest diseases: deciduous fruits, berries, vegetables and root/tuber crops. *Annual Review of Phytopathology*26, 433–469.
15. Papavizas, G.C. (1985). *Trichoderma and Gliocladium Biology, Ecology and potential for bio control*. *Ann. Rev. Phytopathol.*, 23, 23-54.
16. Desai S., Reddy M. S., Kloepper J. W. (2002). “Chapter 17: Comprehensive testing of bio control agents,” in *Biological Control of Crop Diseases* ed. Gnanamanickam S. S., editor. (New York, NY: Marcel Dekker ;) 387–420.
17. Hussey, N. W. & N. Scopes. (1985). *Biological pest control: the glasshouse experience*. Cornell Univ. Press, Ithaca.
18. Aino M, Maekawa Y, Mayama S, Kato H (1997). Bio control of bacterial wilt of tomato by producing seedlings colonized with endophytic antagonistic pseudomonas. In: Ogoshi A, Kobayashi K, Homma Y, Kodama F, and Kondo N, Akino S (Eds) *Plant growth promoting rhizobacteria: present status and future prospects*. Nakanishi Printing, Sapporo, pp 120–123.
19. Baker, K.F., (1987). Evolving concepts of biological control of plant pathogens. *Annu. Rev. Phytopathol.*, 25: 67-85.
20. Heydari, A., H. Fattahi, H.R. Zamanizadeh, N.H. Zadeh and L. Naraghi, (2004). Investigation on the possibility of using bacterial antagonists for biological control of cotton seedling damping-off in greenhouse. *Applied Entomol. Phytopathol*, 72: 51-68.
21. Parrella, M. L. (1990). *Biological pest control in ornamentals: status and perspectives*. *SROP/WPRS Bull. XIII/5:161-168*.
22. Pimentel D, Acquay H, Biltonen M, Rice P, Silva M, Nelson J, Lipner V, Giordano S, Horowitz A and D’Amore M (1992). Environmental and economic costs of pesticide use. *Bioscience* 42:750-760.
23. Jacobsen S-E, Jensen CR, Liu F (2012). Improving crop production in the arid Mediterranean climate. *Field Crops Res* 128:34–47.
24. Fravel, D.R., Olivan, C., Alabouvette, C., (2003). *Fusarium oxysporum and its bio control*. *New Phytol.* 157, 493–502.

